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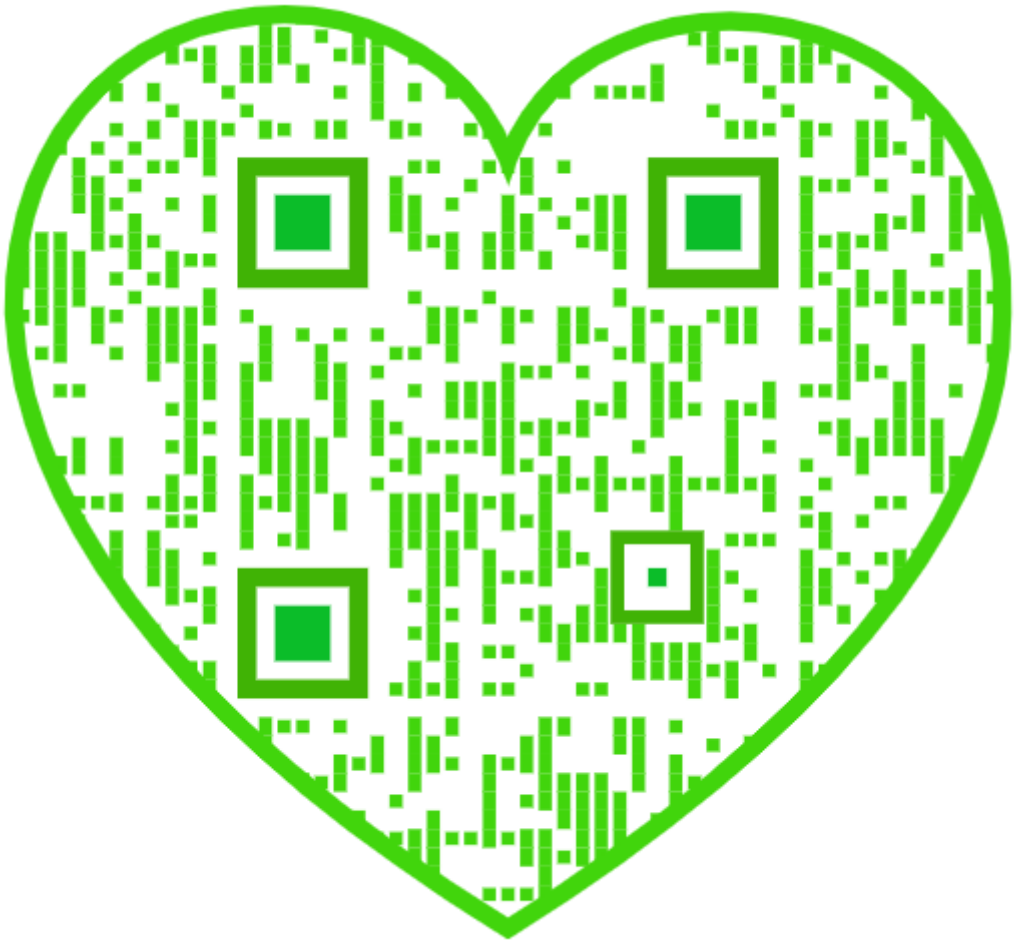

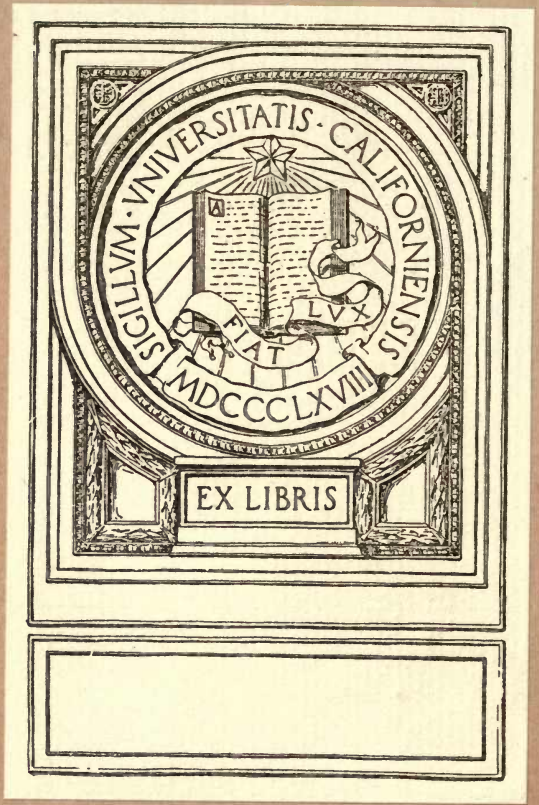
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DEPARTMENT OF MINES
HON. MARTIN BURRELL, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER

MINES BRANCH
EUGENE HAANEL, PH.D., DIRECTOR

BULLETIN No. 21

Occurrence and Testing of Foundry Moulding Sands

Being reprint of a Report appearing in the Annual Summary Report of the Mines Branch for the year ending December 31, 1916.

BY

L. Heber Cole, B.Sc.

OTTAWA
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PREFACE.

No commercial question is of more vital importance to Canada, at the present time, than the energetic development of the natural resources of the country, particularly along the lines of iron and steel. In the past, not only has the greater part of the iron ore smelted in our blast furnaces been imported, but even the sands used in the making of castings in our foundries have been almost entirely imported also. Knowing from surveys made that we have immense deposits of sands and sandstones in various parts of the country, which have never been exploited, nor tested as to their economic value, it was decided, in 1914, to begin a series of technical investigations of the sands of the Dominion—especially those indicating suitability for foundry purposes; and this bulletin by Mr. L. Heber Cole, is a preliminary record of the tests made, and original research work done in connexion therewith.

It is hoped that the facts and data furnished, may be of practical value to those engaged in the iron trade, and particularly those interested in the applied science of founding in metals.

(*Signed*) **Eugene Haanel,**
Director Mines Branch.

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OCCURRENCE AND TESTING OF FOUNDRY MOULDING SANDS.

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THE OCCURRENCE AND TESTING OF FOUNDRY MOULDING SANDS.

INTRODUCTORY.

The need, in Canada, for foundry moulding sands of different grades, suitable for different classes of castings, has increased greatly in the last few years, and has led the Mines Branch of the Department of Mines to investigate many Canadian sand deposits, to determine their suitability for this class of work. At the present time, a large part of the sand used in Canadian foundries is imported and, although, in a number of instances, local deposits furnish small quantities to foundries in the immediate vicinity, no deposits have been opened out on such a scale as to furnish properly graded sand to the general foundry trade of Canada, the supply being drawn mostly from the United States.

In the summer of 1914, investigation of the sand deposits of Quebec was commenced by the Mines Branch, the field work being continued during the seasons of 1915 and 1916, and extended into eastern Ontario. During the season of 1917, field work will be carried on in western and southwestern Ontario.

In the course of the regular field work, several deposits of sand were encountered, which, based on field examination, gave promise of being suitable for moulding sands. Samples of these were taken, and sent to the Mines Branch Laboratories, Ottawa, for examination and testing.

FOUNDRY SANDS IN GENERAL.

Foundry sand may be divided into two main classes:—

(1) Moulding sands: or the sand which is used to make the mould, into which the molten metal is actually poured; and,

(2) Core sands: which are utilized for making the cores that occupy the hollow spaces in the casting.

The material used for foundry sands varies greatly according to the nature of the casting, the metal to be poured, the particular part of the mould, and the foundry where employed. Thus, materials varying from a heavy clayey loam, to a coarse river sand, are used according to the nature of the casting being made. A sand which is suitable for a coarse casting would not be satisfactory for fine work, so, too, a different grade of sand entirely is frequently used for making the cores. Again, in green sand moulding the sand used differs from that used in dry sand moulding—where the moulds and cores are first baked. The practice in various foundries is so diverse, and the sand employed for different grades of castings varies so widely, that it is almost impossible to lay down a hard and fast set of standards to which a sand must conform in order to be called a foundry sand. This is partly due to the manner in which the average foundryman looks on his sand, and partly to the lack of accurate knowledge as to the behaviour and action of certain sands with regard to the castings made in them. The sand used in most cases is employed on the advice of the foundry superintendent, who generally trusts to his practical experience in the handling of sands, as to the suitability of a particular sand for the work in hand. The appearance of the sand to the eye, and whether it will retain the impress of the hand when damp, are generally all the tests to which the sand is subjected. If the moulder does not like the look of the sample submitted, and, especially, if he knows it is a local sand, it is frequently condemned as not suitable without further examination. While

this condition of affairs exists, it will be hard to adopt any standards for moulding sands, but it is conceivable that, when the qualities of different sands in relation to the class of castings made in them have been more fully studied, it will most likely be possible to formulate a set of standards with limits within which a sand may be determined to be suitable for a certain class of casting by systematic laboratory and foundry tests.

THE OCCURRENCE OF MOULDING SAND.

Natural Moulding Sands.

Moulding sands occur in two main types of deposits; but variations of these types may be encountered. These are:—

(a) From flood plain deposits, and
(b) Re-washed ancient beach sands.

(*a*) *Flood plain deposits.*

From the nature of a moulding sand—it being essentially a silica sand. with each individual grain coated with a bonding material—one would expect to find it occurring where deposits of sand and clay were constantly being intermingled, and worked over by water, and as a matter of fact, moulding sands in flood plain deposits are of quite common occurrence. In these beds the sand and clay have been well and intimately mixed by the river currents, and deposited on the higher levels in flood time; the excess of clay, being more *minute*, is carried off by the water.

One would thus expect to encounter moulding sands of this character along the upper terraces of the larger rivers of the country, such as the St. Lawrence; also along the banks of the ancient waterways.

(*b*) *Re-washed, ancient beaches.*

The second class of deposits which are frequently encountered are of secondary origin. The sand bars and beaches of the ancient seas have been worked over by the waves as they recede, when new levels of the lakes and seas are formed. The washed material from these beaches consists of sand and clay, the former being deposited in greater abundance. It is in deposits of this class, which are found at a lower level than the old beaches or water margins, that moulding sand may be expected to occur. These deposits are, therefore, to be looked for in the vicinity of the ancient glacial lake margins, such as the Iroquois and Algonquin, which formerly occupied the Great Lake Basin; and also within the boundaries of the ancient Lake Agassiz in Manitoba. Similar ponded water bodies in glacial times—extending as far as the foot-hills of the Rocky mountains in Alberta—may also have deposits of this character within their margins.

Prepared Moulding Sands.

The natural moulding sands referred to above comprise by far the greater part of the sand used in Canadian and United States foundry practice; but there are being employed increasing amounts of what may be termed "prepared moulding sands;" and as the suitability of this class of sand becomes better known there is no doubt that their use will be widely extended. These sands are prepared for use by crushing either sandstones which have a very friable bonding material, decayed granite, or shattered sandstone having the fractures filled with a plastic material (such as kaolin, etc.). These sands have no fillers added to them, but have perhaps to be screened and washed, as well as crushed, before being offered to the trade.

Under this class may also be placed those earthy loams which, by washing—to remove part of the clayey content—may be utilized as a suitable foundry sand.

Synthetic Moulding Sands.

Many foundrymen have stated that they feared it is quite possible that the present known deposits of high grade natural moulding sand will become exhausted, and that resort will have to be had to artificial or synthetic moulding sands made by intimately mixing finely crushed quartz, or clean, sharp sand, with clay, so that each grain of quartz would become uniformly coated with the clay. It can readily be seen that sand so prepared will have decided advantages over the sands at present in use, in that it will be possible to manufacture a uniform material for the class of work required, and also that variations in the material can be made at will to meet the requirements of the trade.

THE TESTING OF MOULDING SANDS.

The examination and testing of a moulding sand deposit can be divided into two parts:—

(a) The field examination of the deposit.
(b) Laboratory examination and testing of the sands.

Field Examination of a Sand Deposit.

In undertaking a field examination of a moulding sand deposit, there are several points to be taken into consideration:—

1. Nature and extent of the deposit (area and depth).
2. Uniformity of sand.
3. Transportation facilities.
4. Location, with respect to the larger markets.

The importance of a field examination can readily be seen. A sand may be suitable for foundry work in every way; but, if it is not in sufficient quantity, easily exploited, and is not favourably situated to the larger markets for this class of material, the deposit is of little value as a commercial venture.

The method of field examination employed by the writer is as follows: The area is tested by drilling test holes with a 6″ post hole auger drill, in a sufficient number of places to determine the extent and depth to which the sand is encountered. These holes are indicated on a map of the area and the boundaries of the sand plotted. The sand encountered in the drill holes is carefully examined with a hand magnifying glass to note any marked difference in its character. Samples are taken from these holes and mixed together to obtain a uniform sample for testing in the laboratory. If more than one grade is noted, separate samples are taken.

Laboratory Examination and Testing of Sands.[1]

On commencing the laboratory tests of the samples taken in the field, the question arose, "What are the requirements of a good moulding sand?" The literature on moulding sands is very meagre, and any systematic series of laboratory tests to determine a sand's suitability for a foundry sand are confined to work done by several of the State Surveys, the Bureau of Standards, Washington, and the American Foundrymen's Association. The opinions of the investigators appear to differ greatly both as to the series of tests necessary, as well as the method by which they are to be carried out.

From a study of the literature available, and after numerous conversations with practical foundrymen throughout the country, it was found that the qualities to be taken into consideration in the examination of a moulding sand are as follows:—

---

[1]The sands referred to are moulding sands proper. Core sands vary widely in different localities, and mostly require bonding material to be added to them. They will be treated separately at a later date.

Texture.

The texture or fineness of grain is one of the most important points of a sand. This will necessarily vary, according to the size and kind of casting to be made in it. Hence, it is at once obvious that sands will have to be selected to suit the class of work for which they are required, or, in other words, sand which is suitable for light work would, perhaps, be a failure when used with heavy work, or vice versa.

Refractoriness.

The capability of effectively resisting the destructive action of the heat of molten metal, is of importance. The greater the size of the casting, the longer it will be in cooling, hence the sand in contact with the metal will be subjected to the intense heat for a longer period of time. It is obvious, therefore, that for large castings, a more highly refractory sand will be required than for small castings.

Bonding power.

Moulding sands should possess sufficient bonding power, or cohesiveness of their particles to each other to retain firmly the shape and form of the pattern; and also to resist the pressure of the molten metal in the mould. This bonding power depends partly on the clay mixed through the sand particles, and the clay coating on the individual grains, and partly on the nature of the grains, whether they are angular or rounded, coarse or fine. As a rule, the finer and more angular the sand grains, the greater the bonding power.

Permeability.

One of the properties of a moulding sand which helps to determine its suitability for foundry use is that of allowing the escape of gases through it. The molten metal develops gases which exert a pressure on the face of the mould and, unless the spaces between the grains are sufficient to enable the gases so generated to escape freely, there will be serious danger of creating scabs, or causing the castings to blow on this account. Obviously, then, heavy castings will require a more open sand of a coarser grained texture than will fine castings.

Durability.

The durability or life of a sand is of great importance. There are many sands which, when used once or twice, lose some of their desirable qualities, and soon become "dead" or useless. It is manifest that the sand in contact with, and adjacent to, the molten metal will suffer most. The present practice is to screen out the coarse particles, and add fresh sand to the remainder. The greater the durability of a sand, the better it is, as it will last longer, and it will not be necessary to add fresh sand to it so frequently.

In deciding upon the methods to be employed in examining the samples taken—with a view to ascertaining their characteristics regarding the qualities just enumerated, it was decided to proceed as follows:—

The sample for examination is first passed through a 10 mesh screen, and what is retained on this screen is considered the sample for examination; and all tests are conducted with this material.

ACTUAL TESTS.

Texture.

The texture is determined by making a granulometric analysis of a representative sample, generally 100 grams. This is passed through a series of Tyler standard screens, by shaking for a definite length of time on a mechanical

shaker; the material retained on each screen being collected, weighed, and noted. If the sample, in the first place, weighs 100 grams, the weight recorded as retained on each screen is the percentage retained on that screen; and the cumulative percentage of all material that would be retained on any given screen, if that screen alone were employed, can readily be determined. The screens used for this test and the form used for tabulating the results are as follows:—

Indicate the screen crushed through and also first retaining screen	SCREEN SCALE RATIO 1·414				WEIGHTS		
	Openings		Mesh	Diameter wire inches	Sample weights	Per cent	Per cent cumulative weights
	Inches	Millimetres					
.....	·065	1·651	10	·035	.....	.....	.....
.....	·046	1·168	14	·025	.....	.....	.....
.....	·0328	·833	20	·0172	.....	.....	.....
.....	·0232	·589	28	·0125	.....	.....	.....
.....	·0164	·417	35	·0122	.....	.....	.....
.....	·0116	·295	48	·0092	.....	.....	.....
.....	·0082	·208	65	·0072	.....	.....	.....
.....	·0058	·147	100	·0042	.....	.....	.....
.....	·0041	·104	150	·0026	.....	.....	.....
.....	·0029	·074	200	·0021	.....	.....	.....
Pass.....	·0029	·074	200	·0021	.....	.....	.....
				Totals,	.....	.....	.....

In order to gain some idea of the relative fineness of the sand, and to be able to express this in one figure, a more convenient form than the whole granulometric analysis, the average fineness of the sample is calculated. The average fineness is determined as follows: the material passing through each screen and retained on the next smaller, is multiplied by the mesh of the screen passed through. The results obtained are totalled and divided by 100, the resultant being the average fineness. In other words, if all the grains of the sample were reduced to a uniform size, they would just pass through a screen whose mesh was equal to the average fineness of the sample. For example the granulometric analysis of a sand is:—

	Mesh	%	The calculations for average fineness will be	
Retained on	10			
„	14		14 × 0·10 =	1·40
„	20	0·10	20 × 0·12 =	2·40
„	28	0·12	28 × 0·23 =	6·44
„	35	0·23	35 × 0·65 =	22·75
„	48	0·65	48 × 0·72 =	34·56
„	65	0·72	65 × 1·50 =	97·50
„	100	1·50	100 × 13·01 =	1301·00
„	150	13·01	150 × 22·30 =	3345·00
„	200	22·30	200 × 61·37 =	12274·00
Through	200	61·37	Total	17085·05

$$\text{Thus } \frac{17085 \cdot 05}{100} = 170 \cdot 85$$

or the average fineness of the sample is 170·85.

Microscopic Examination.

It has been found that the free use of the microscope in examining the sand, both fresh and after being burned, has added valuable data which helps materially in determining a sand's suitability for a moulding sand. Microphotographs of the sand are also valuable for comparison.

Refractoriness.

The refractoriness of a sample is determined by preparing a cone of the sand and heating it to fusion in an electric furnace along with standard Seger cones, and noting at what cone the sand fuses.

Bonding Power.

The determination of the bonding power of a moulding sand from tests either in a laboratory or in actual foundry practice presents many difficulties, and the methods so far devised give only relative results, and these are variable according to the skill of the operator in making the tests. The tentative method adopted for these tests is similar to the method employed by the Bureau of Standards, Washington, D.C., with a few slight modifications. By this test the transverse strength of the sand is determined. A known quantity of a particular sand is weighed (generally 500 grams), and mixed with a definite quantity of water, so that the sand will just hold together. From this sand, a test bar is made, one inch square, in section, by 12 inches long. This is moulded in a snap flask on a piece of plate glass.

The sand is packed in the flask as uniformly as possible from end to end with the thumb and forefinger of each hand, and smoothed with a trowel. The flask is removed, and the test bar, is left on the plate. The glass plate and bar are then weighed, the weight of the glass plate having been previously determined, and the weight of the test bar is obtained by difference.

While the test bar still retains its moisture, it is gently and steadily shoved lengthwise over the edge of the glass plate until it breaks off and the length breaking off is noted. Continuing this operation, successive portions are broken off and the average length of the overhang at the breaking moment is determined. The weight of the bar in grams being known, the transverse strength of the specimen can be calculated from the following formula:—

$$S = \frac{W}{4} \times \frac{L^2}{453 \cdot 6}$$

S = transverse strength in lbs. per sq. in.
W = total weight of bar in grams.
L = length of overhang in inches.

A series of tests were conducted on each sample, taking 5 c.c. additional water each time until the test bar deforms on attempting to shove it over the edge of the glass. An average of the transverse strength results obtained by using varying quantities of water is taken to represent the transverse strength of the specimen.

Permeability.

The method adopted for the determination of the permeability of a moulding sand is, as far as the writer knows, entirely new. Investigations along this line have consisted in passing either a definite amount of water or air through the sand, and noting the time required. Both these methods introduced a serious error, since once the first air or water had passed through the sand, channels would be opened through the sand which would greatly facilitate the flow of the remainder of the air or water. To overcome this difficulty the apparatus shown in Fig. 1 was

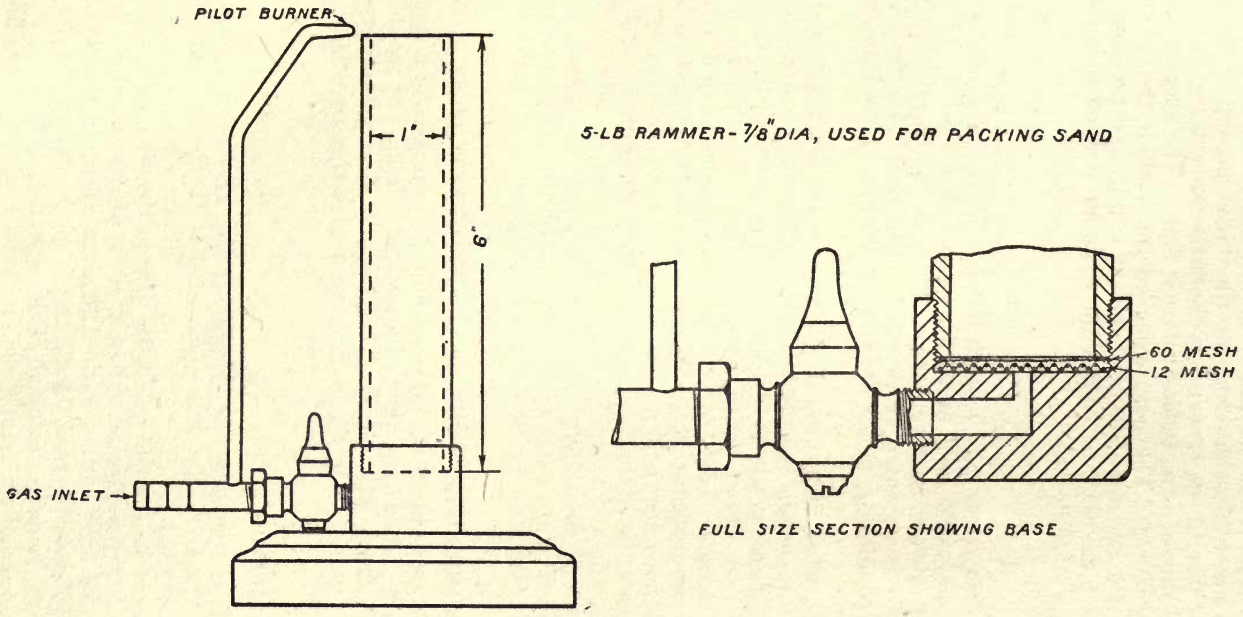


Fig. 1. Apparatus for determining permeability of moulding sands.

designed, and the results so far obtained have been extremely satisfactory. With this apparatus, ordinary illuminating gas at a definite pressure is passed through the sand, and ignited the instant it reaches the top of the sand tube. The interval of time required from when the gas is turned on, to the moment of ignition, is noted by a stop watch, thus determining the initial passing of the gas, and overcoming the error due to the forming of channels through the sand. Three tests are run on each sample, using fresh sand each time. The average time is taken as the permeability factor. The sand is packed uniformly in the cylinder by placing in a small quantity at a time (about 1 inch of sand), and pressing it down for 5 seconds, using a 5 lb. weight. When the cylinder is filled it is struck off flush on the top with a straight edge.

Durability.

All the foregoing tests may be regarded as a preliminary inquiry as to whether any sand can be classed as a moulding sand and passed on to the durability test, which must always be regarded as the final one by which a sand from an unworked deposit is accepted or rejected. The durability test is made under actual working conditions, hence definite knowledge of the usefulness of a sand can be determined.

If a sample, when subjected to the previously described tests, has proven satisfactory within certain accepted limits, a larger sample is obtained and tested in a commercial foundry, where castings are being made of the class to which the sand is deemed best suited. A pattern is chosen, usually, one which comes in the general run of the foundry, and the sand to be tested is used with this pattern. Care is taken to keep separately the sand in which the casting is made, and another cast from the same pattern is made, using this sand without any fresh added. This operation is repeated until the sand shows signs of becoming "dead." After each cast, the sand is thoroughly mixed and a sample taken. These samples are submitted to all the laboratory tests previously described, and any differences noted. For means of comparison, a duplicate series of castings is made in parallel with the sand being tested, employing some well-known moulding sand.

TEST OF A MOULDING SAND COLLECTED NEAR BROCKVILLE, ONT.

To illustrate the methods employed in the examination and testing of a moulding sand the following report of a test on a deposit of moulding sand from near Brockville, Ont., will serve, This deposit was one encountered in the course of the regular field work, in connexion with the investigation of the sand deposits of Ontario.

Field Examination.

The deposit in question lies 2½ miles to the west of the town of Brockville, Ont., between the G.T. Ry. line (Montreal to Toronto), and the river road, (Brockville to Belleville).

As far as could be determined in the time at the disposal for the field examination, the area underlain by moulding sand is of considerable extent, although detailed work was only carried out on the area shown in the sketch map Fig. 2. No time was available to trace the extension of the deposit to the east or to the west, but this will be done during the field season of 1917.

The topography of the immediate district is decidedly rugged in appearance. The drift with which the district is overlain consists of rolling hills of boulder clay, sand, and gravel, through which numerous "islands" of bare rock protrude. These patches of bare rock consist, to the north and northeast, of Potsdam (?) sandstone, and, to the south and west, of Laurentian granites. All outcrops of rock examined were well glaciated, and rounded, showing clearly defined striæ.

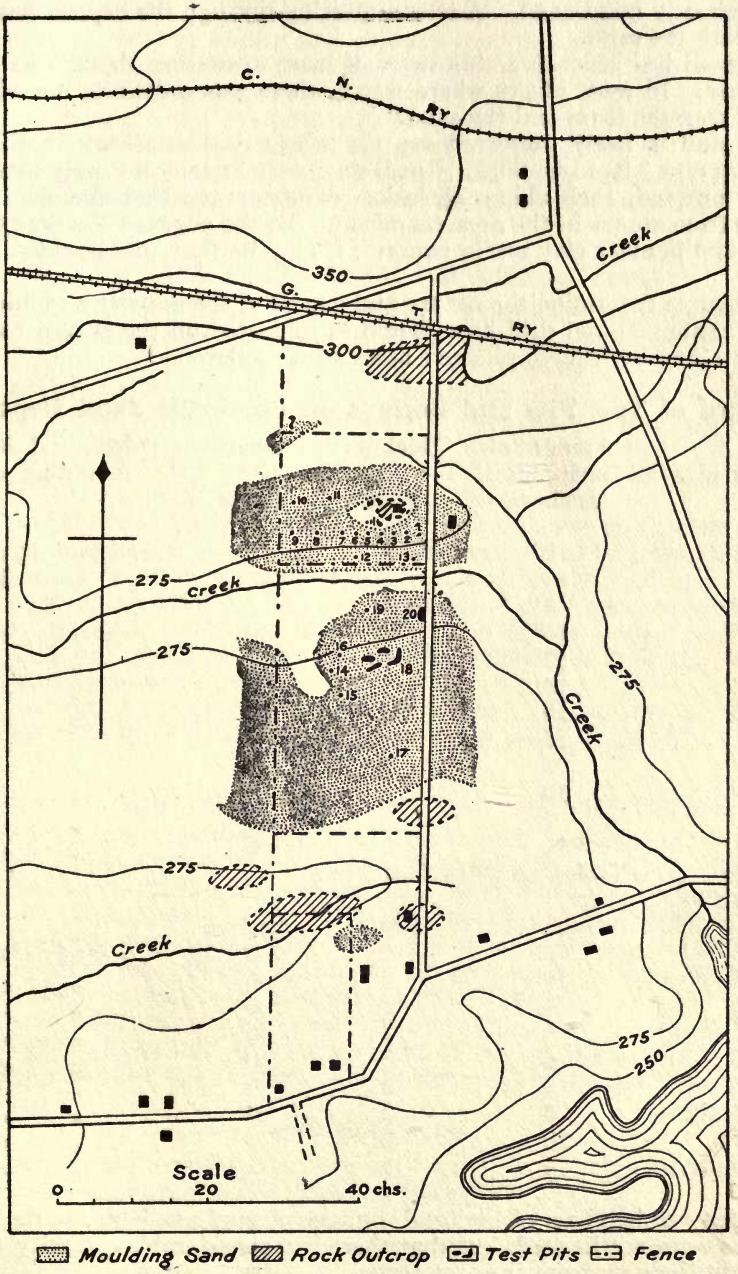


Fig. 2. Sketch map showing areas underlain by moulding sand on the property of T. H. Bresee and others, 2½ miles west of Brockville, Ontario.

By reference to the sketch map Fig. 2, it will be seen that the area so far known to be underlain by moulding sand lies between and around the rock outcrops already mentioned. A stream passing through the deposit has revealed clay beneath the sand.

The sand lies beneath a thin layer of loam averaging about 6 to 12 inches in thickness. In most places where tested, there was a definite line of demarcation between the loam and the sand.

The sand is fairly uniform over the whole deposit shown in the sketch, and will average 2 ft. 4 ins. thick. In all the test holes and pits, only two boulders were encountered, each about 2½ inches diameter; so that the sand appears to be free from stones in the area examined. To the edges of the deposit, where the sand and boulder clay are in contact, it may be that the boulders are more frequent.

In order to determine the nature and extent of the deposit a number of test pits were examined and drill holes bored as indicated on the sketch map. The results obtained from these pits and holes are as follows:—

Record of Test Pits and Borings on Brockville Sand Deposit.

Hole or pit.	Amount of stripping. Inches.	Thickness of moulding sand. Feet	Inches.	Material below moulding sand.
1	8	3	8	sand and clay interbanded
2	8	3	4	do
3	14	1	0	sandy clay.
4	12	1	2	" "
5	10	1	6	" "
6	10	3	10	" "
7	15	1	9	" "
8	8	2	0	" "
9	10	1	10	" "
10	7	2	2	" "
11	10	2	6	" "
11a	stiff clay to a depth of 3 feet.			
11b	" Inches "	" Feet "		
12	6	2	0	sandy clay.
13	10	1	6	" "
14	4	2	6	" "
15	8	2	6	" "
16	6	3	0	" "
17	8	2	0	" "
18 pit.	8	2	6	" "
19	10	2	8	" "
20 pit.	4	3	2	" "

No idea can be given of the total tonnage of sand available, as the complete boundaries were not located, but that there is a considerable quantity there can be no doubt, judging from the area tested.

Preliminary Tests.

A sample of 40 pounds of sand was taken when the deposit was first visited, and this was applied by the Alex. Fleck, Ltd., foundry, Ottawa, to make moulds for three iron castings; one at a time, using the Brockville sand, exclusively,

each time. The weight of the casting was about 12 pounds, and all three casts were perfectly satisfactory, having a good smooth surface, free from scabs, and corners showing clean definition.

This preliminary test having proved satisfactory, two lots of 600 pounds each, were dug, and shipped by the writer to Ottawa, without preparation in any way, in order to test the lasting and wearing qualities of the sand. Care was taken to see that the samples collected were representative of the whole deposit as far as could be ascertained. One shipment was taken to the foundry of Alex. Fleck, Ltd., Ottawa, where the first tests were made; and the other 600 pounds was delivered to the brass foundry of Lawson Bros., Ottawa.

At both places the tests carried on were made under the supervision of the writer, who followed closely all the results obtained, and examined the sand and castings after each cast.

TEST OF SAND AT THE FLECK FOUNDRY, OTTAWA.

It was desired to gain an idea of the life of the sand when employed with fairly heavy pieces of casting. In order to obtain comparative results, the same amount of fresh No. 3 Albany moulding sand—as used in this foundry was taken— and used side by side with the Brockville sand on the same pattern. After each cast, each sand was kept separate, thoroughly mixed, sampled, and used again, The piece cast was an iron flange in the shape of an L, 5 feet long, 10 inches wide, and 1 inch thick; with a 3 inch flange 1 inch thick, on one side. The weight of the casting was approximately 200 pounds.

Five castings were made in each sand under ordinary working conditions, the moulding being done on the two sands by the same moulder throughout, under the direct supervision of the foreman. Care was taken that each sand was thoroughly mixed after each casting. A sample of each sand was taken when fresh, and after each burn, and examined in the Mines Branch Laboratories. No fresh sand was added to either test, and only the sea coal that was absolutely necessary was employed.

The castings were examined after each cast. There was no noticeable difference between those cast in either sand, or from the first and fifth cast in the same sand.

TEST OF SAND AT THE LAWSON BRASS FOUNDRY, OTTAWA.

The sand sent to Lawson Bros. was used in their brass foundry on general run of work, employing whatever pattern they needed each day. The Brockville sand was kept separate throughout, and the cast was varied between brass and iron, all castings being small. The sand was mixed thoroughly after each burn and no fresh sand added to it. Samples after every alternate burn were taken for examination. Seven castings in all were made in the same sand, the weight of castings varying from 12 to 50 pounds. Five were brass, and two iron. All castings showed clear, sharp, well defined edges, and the body free from scabs. No sign of burning appeared on any of the castings. A sample of the fresh Albany sand, No. 0, as used in this foundry, was taken for comparison.

Laboratory Tests.

The samples for examination—obtained from the casting tests at the two foundries—were subjected to the following laboratory tests.

GRANULOMETRIC TEST.

The samples as brought from the foundries were each treated as separate samples. Each one was thoroughly mixed and quartered, and 100 grams taken, and put through a set of Tyler Standard Screens, on a mechanical shaker. The results obtained are tabulated in Table I.

TRANSVERSE STRENGTH.

The test for determining the transverse strength or bonding power of the sand was carried out in a similar manner to that employed in the Bureau of Standards, Washington, D.C., U.S.A., with the exception of always taking the same amount of water. A series of tests were run on each sample, varying the amount of water 5 c.c. each time, and taking the average of results obtained as the transverse strength. The results of the tests are given in Table II.

TEST FOR REFRACTORINESS.

A test for the refractoriness of the fresh Brockville sand was made by preparing a cone and fusing it in an electric furnace with Standard Seger cones. The test cone fused at cone 8 which is equivalent to 1290 degrees C. or 2354 degrees F.

Microscopic Examination.

The fresh sand, as well as the samples from each burn, were examined under a binocular microscope, and the following notes made:—

No.		
1	No. 3, Albany fresh sand. (*Fleck foundry*).	Small grains, well rounded. Larger grains, semi-angular. Quartz predominant. Occasional grain of magnetite; all were coated with clay and of uniformly yellowish colour.
2	„ „ 1st. burn.	Quartz grains in some cases have the clay partially burned off. Sintering is seen in a few cases in the smaller grains. In most cases sand grains are unchanged.
3	„ „ 2nd. burn.	Similar to No. 2 with exception that the sand has a darker appearance, due to occasional grains having turned reddish in colour from the oxidation of the ferric iron coating.
4	„ „ 3rd. burn.	Sand has a darker appearance. Sintering more pronounced. Cementing of groups of the smaller grains together. Larger grains losing their clay coating to a small extent.
5	„ „ 4th. burn.	Similar to No. 4 with the grouping together of the smaller grains more pronounced.
6	„ „ 5th. burn.	Large grains have taken on the appearance of spongy masses due to the adhering of the smaller particles to them. Smaller particles are grouped and cemented together still further. Sintering quite pronounced. Occasionally edges of larger grains are fused.
7	Brockville fresh sand. (*Fleck foundry*).	Sand consists of fairly clean quartz sharp and angular with only a very thin film of clay coating. Magnetite, hornblende, feldspar, and mica visible. Light yellowish colour.
8	„ „ 1st. burn.	Sintering appearing. Sand assuming a darker colour.

No.

9 Brockville sand, 2nd. burn. (*Fleck foundry*). Sintering quite pronounced. Larger grains have smaller grains cemented to them and the smaller grains commencing to group together in cemented masses.

10 „ „ 3rd. burn. Sintering and cementing together of small particles more pronounced. Sand grains showing decided effect of heat.

11 „ „ 4th. burn. Complete fusion in mass of some of the smaller groups of particles can be seen. The edges of most of the larger grains have become fused and present an appearance of water-worn sand.

12 „ „ 5th. burn. Sintering pronounced in most of the grains. Small grains are grouped together and well fused. Larger grains show fusion of sharp edges. Bonding coating has disappeared from the greater percentage of grains.

13 Brockville fresh sand. (*Lawson foundry*). Coating slightly affected. No sign of sintering.

1st. burn. Sand similar in appearance to original.

14 „ 3rd. burn. No sign of sintering. Coating only slightly affected. Otherwise similar to original.

15 „ 4th. burn. Same as No. 14.

16 „ 5th. burn. Same as No. 15 with slight signs of sintering.

17 „ 7th. burn. Slight sintering. Smaller particles in some cases cemented together.

18 No. 0 Albany fresh sand. Highly siliceous sand. Uniformly graded and coated. Sand particles sharp and angular. Light yellow in colour.

Microphotographs of each sample were taken, and are shown in Plates VI, VII, and VIII. (See plates at end.)

Chemical Analysis.

A chemical analysis of the Brockville sand was made, with the following result:—

Ultimate Analysis.

SiO_2	74·35 per cent.
Fe_2O_3	1·10 „ „
FeO	1·48 „ „
Al_2O_3	12·63 „ „
CaO	2·60 „ „
MgO	1·06 „ „
Na_2O	2·73 „ „
K_2O	2·15 „ „
H_2O	1·90 „ „

It is questionable whether much information can be obtained from ultimate analysis, beyond a very general indication of the refractoriness, and is moreover frequently very misleading, hence it is deemed advisable to omit it in future.

Permeability Test.

The permeability test shows that the permeability increases the oftener the sand is subjected to the molten metal. Results are given in Table III.

CONCLUSIONS DEDUCED FROM RESULTS OF TESTS.

An examination of the results obtained from the series of tests carried out on this sand brings out some interesting facts regarding the properties of moulding sands, and their behaviour under actual working conditions.

Granulometric Analysis.

By comparing the No. 3 Albany screen analysis with the Brockville sand used at the Fleck foundry, it will be seen that there is in both cases increase in the coarseness of the particles, the oftener the sand is submitted to the heat of the molten metal. In the case of the No. 3 Albany, this increase is uniform and very gradual; whereas with the Brockville sand the changes are abrupt, and not uniform, showing a tendency of the smaller particles to become cemented together. On the other hand, the Brockville sand as used at the Lawson foundry, shows only a slight increase after each burn, and the increase is uniform.

Tests for Transverse Strength.

In examining the results obtained by the tests for transverse strength it is seen that both in the No. 3 Albany and the Brockville sand used at Fleck's, there is a gradual decrease in the amount of water used and also a decided decrease in the transverse strength. In the case of the Brockville sand used at Lawson's the decrease in strength is only slight.

Microscopic Examination.

By microscopic examination of the samples obtained after each burn, and also the fresh sand, some interesting data were secured. The Brockville sand (Fleck's), shows decided sintering and cementing together of the smaller grains to the larger ones, with a consequent decrease in bonding power. This sintering and cementing together of the particles is shown plainly in the microphotographs, Plate VII. The sand tested at Lawson's shows very little alteration when examined under the microscope.

Chemical Analysis.

The conclusions to be drawn from the chemical analysis are so slight that it can be dispensed with in an examination of this kind, the physical tests being the only ones of value.

SUMMARY OF RESULTS.

Summing up the results obtained in the tests, it appears that the Brockville sand is a suitable moulding sand for stove plate and similar light work in iron, but although the heavier castings made in it were seemingly all right, it would not be advisable to use it on very heavy work, as the possibility of its failure would be greater than the coarse sands in general use, owing to the fineness of its texture with the resultant tendency to sinter when exposed repeatedly to the molten metal.

It appears to answer all requirements for use in the general run of brass foundry work. With a little care in selection and grading at the pit, several grades uniform in texture could be obtained.

TABLE I.

Granulometric Tests.

Cumulative per cent of material retained on given meshes.

		6.	8.	10.	14.	20.	28.	35.	48.	65.	100.	150.	200.	200+	Average Fineness.
Brockville (Fleck's).	Green sand..	—	—	—	—	·09	·24	·46	·69	1·63	8·85	49·95	77·21	—	132·9
	1st. burn....	—	—	·27	·80	2·01	4·14	8·83	19·54	28·83	40·27	67·83	82·87	—	102·0
	2nd. „	—	—	·18	·36	·78	2·00	4·88	12·00	16·95	28·80	60·27	80·79	—	114·4
	3rd. „	—	—	·41	·89	2·01	3·91	8·84	20·18	27·70	41·96	68·35	83·00	—	94·7
	4th. „	—	·30	·80	1·26	2·17	4·46	8·68	19·70	29·03	41·23	70·26	85·12	—	99·21
	5th. „	—	·31	·74	1·41	2·46	5·15	10·98	24·60	34·05	48·09	72·46	80·02	—	96·6
No. 3 Albany (Fleck's).	Green sand..	—	—	·40	1·00	1·98	4·65	13·08	34·03	50·65	65·96	78·51	83·77	—	81·3
	1st. burn....	—	—	·69	1·30	2·47	4·74	12·37	32·82	50·66	66·85	79·58	85·55	—	79·7
	2nd. „	—	·36	·91	1·56	2·76	5·55	13·72	36·09	52·11	68·03	79·65	86·01	—	78·2
	3rd. „	—	·40	1·03	1·86	3·52	6·68	16·13	36·52	54·18	69·33	82·22	82·34	—	77·5
	4th. „	·42	·92	1·43	2·13	3·39	6·89	16·53	39·35	54·37	70·24	82·68	87·90	—	73·5
	5th. „	—	·50	·90	1·63	2·89	6·23	15·68	37·71	52·85	68·96	81·30	87·78	—	75·6
Brockville (Lawson's).	Green sand..	—	—	—	—	·09	·24	·46	·69	1·63	8·85	49·95	77·21	—	132·9
	1st. burn....	—	—	—	·05	·18	·46	·75	1·22	2·79	11·56	48·43	74·05	—	134·0
	3rd. „	—	—	—	·13	·26	·44	·81	1·21	2·31	10·41	51·75	77·06	—	131·3
	4th. „	—	—	—	·11	·38	·69	1·05	1·42	2·87	11·44	46·25	72·39	—	135·8
	5th. „	—	—	—	·18	·38	·68	1·16	1·93	3·91	12·83	50·46	72·91	—	132·7
	7th. „	—	—	·20	·40	·62	1·02	1·42	3·37	4·22	11·71	49·06	60·75	—	140·1
	*Green sand.	—	—	·14	·46	·88	1·38	2·03	3·01	5·03	11·27	19·46	26·64	—	171·4

*No. 0 Albany (Lawson's).

TABLE II.

Transverse Strength in Pounds Per Square Inch.

(500 grams sand used in all tests; therefore, percentage of water used is double number of c.c. used divided by 10).

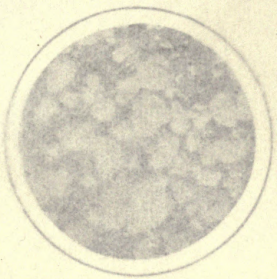
	Water used.	45 c.c.	50 c.c.	55 c.c.	60 c.c.	65 c.c.	70 c.c.	75 c.c.	80 c.c.	85 c.c.	90 c.c.	95 c.c.	Average.
Brockville (Fleck's)	Green sand.....						0·76	0·85	0·87	0·96	0·97	1·01	0·93
	1st. burn.....						0·75	0·84	0·90	0·97	—	—	0·865
	2nd. „						0·86	0·85	0·86	0·81	—	—	0·845
	3rd. „				0·80	0·87	0·89	0·90	—	—	—	—	0·865
	4th. „				0·76	0·75	0·65	0·85	—	—	—	—	0·752
	5th. „				0·76	0·78	0·74	0·79	—	—	—	—	0·767
No. 3 Albany (Fleck's)	Green sand.....		0·74	0·73	0·93	1·07	—	—	—	—	—	—	0·867
	1st. burn.....		0·62	0·71	0·57	—	—	—	—	—	—	—	0·633
	2nd. „		0·57	0·69	0·65	0·74	—	—	—	—	—	—	0·665
	3rd. „		0·65	0·65	0·80	—	—	—	—	—	—	—	0·700
	4th. „		0·62	0·63	0·62								0·623
	5th. „		0·58	0·59	0·55								0·573
Brockville (Lawson's).	Green sand.....						0·76	0·85	0·87	0·96	0·97	1·01	0·903
	1st. burn.....						0·84	0·76	0·84	0·89	0·95		0·856
	3rd. „						0·92	0·97	0·96	0·85	—	—	0·875
	4th. „						0·90	0·92	0·88	0·88	0·85	—	0·886
	5th. „						0·91	0·82	0·97	0·88	—	—	0·895
	7th. „						0·85	0·81	0·84	0·89	—	—	0·847

TABLE II.

Permeability Test.

Time in seconds. Gas pressure = 2·8 inches.

		1st. Trial.	2nd. Trial.	3rd. Trial.	Average.	
No. 3 Albany (Fleck's Foundry).	Fresh.....	4 1/5	5	4	4 3/5	
	1st. burn.....	4	3	3 1/5	3 2/5	60 c.c. water used = 12%.
	2nd. „	2 4/5	2 4/5	2 4/5	2 4/5	
	3rd. „	2 4/5	2 4/5	2 4/5	2 4/5	
	4th. „	3	3 1/5	2 1/5	2 4/5	
	5th. „	2 3/5	2 3/5	2 3/5	2 3/5	
Brockville Sand (Fleck's Foundry).	Fresh.....	19	17 3/5	18	18 1/5	
	1st. burn.....	8	7 3/5	8 2/5	8	
	2nd. „	8	8	9 1/5	8 3/5	70 c.c. water used = 14%.
	3rd. „	5	6	7	6	
	4th. „	7	5 1/5	5 1/5	5 4/5	
	5th. „	5 1/5	6	6 3/5	5 1/5	
Brockville Sand (Lawson's Foundry).	Fresh.....	19	17 3/5	18	18 1/5	
	1st. burn.....	10 3/5	10	10 2/5	10 1/5	
	3rd. „	12 3/5	10 1/5	11	11 1/5	70 c.c. water used = 14%.
	4th. „	8 1/5	8	8 1/5	8 1/5	
	5th. „	11	11 4/5	10 4/5	10 4/5	
	7th. „	8 4/5	7 3/5	6 4/5	7 4/5	
Albany No. 0	Fresh.....	23	23	21 4/5	22 3/5	70 c.c. water used = 14%.



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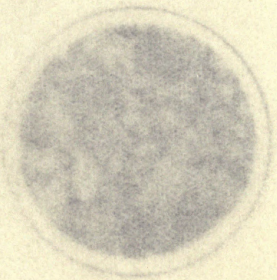


4

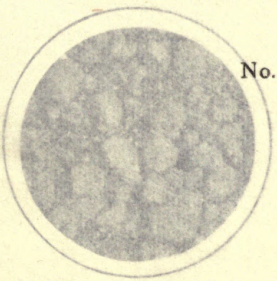
EXPLANATION OF PLATE VI.

Microphotographs

No. 3 Albany Sand

(Oblique reflected light)
(Magnification—12 diams.)

1. Fresh sand,
2. After 1st. Burn,
3. „ 2nd. „
4. „ 3rd. „
5. „ 4th. „
6. „ 5th. „



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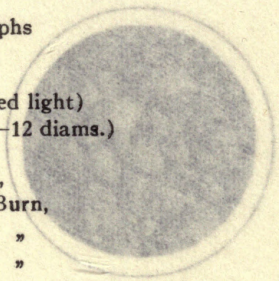

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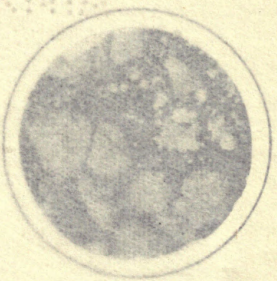


6

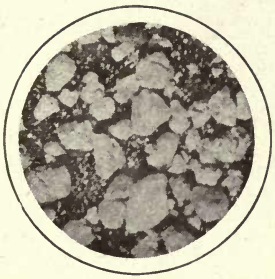
EXPLANATION OF PLATE VI.

Microphotographs

No. 3 Albany Sand

(Oblique reflected light)
(Magnification—12 diams.)

1. Fresh sand,
2. After 1st. Burn,
3. " 2nd. "
4. " 3rd. "
5. " 4th. "
6. " 5th. "



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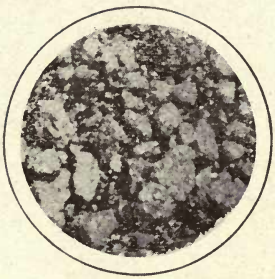

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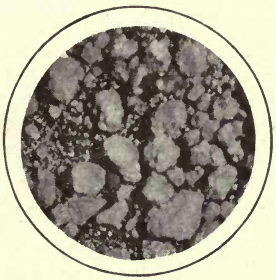

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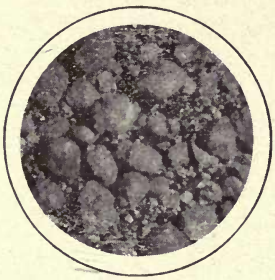

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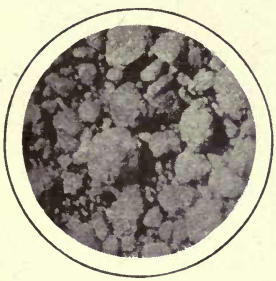

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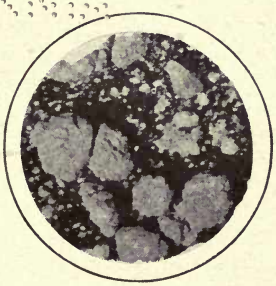

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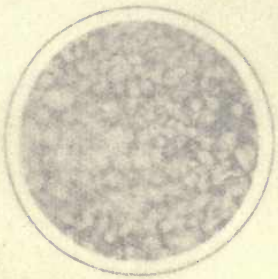
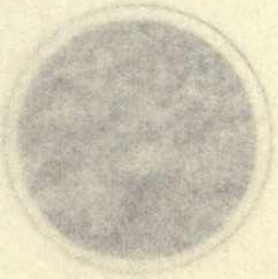




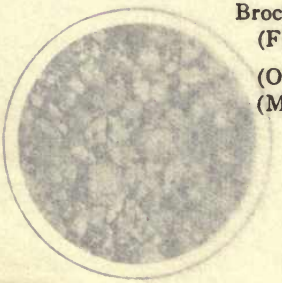
EXPLANATION OF PLATE VII.

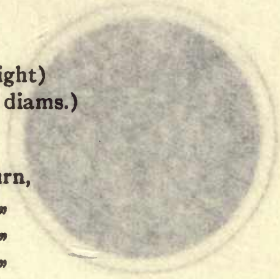
Microphotographs

Brockville Sand
(Fleck's Foundry)

(Oblique reflected light)
(Magnification—12 diams.)

7. Fresh sand,
8. After 1st. Burn,
9. „ 2nd. „
10. „ 3rd. „
11. „ 4th. „
12. „ 5th. „





EXPLANATION OF PLATE VII.

Microphotographs

Brockville Sand
(Fleck's Foundry)

(Oblique reflected light)
(Magnification—12 diams.)

7. Fresh sand,
8. After 1st. Burn,
9. " 2nd. "
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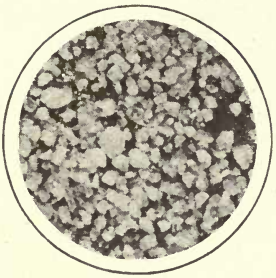
11. " 4th. "
12. " 5th. "



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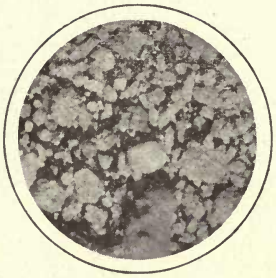

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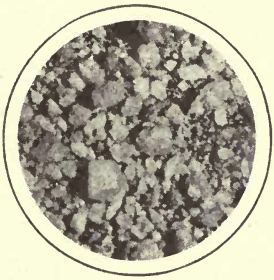

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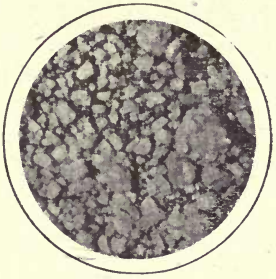

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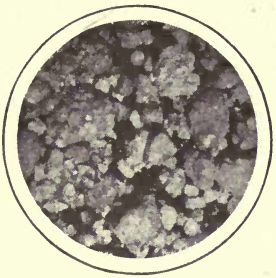

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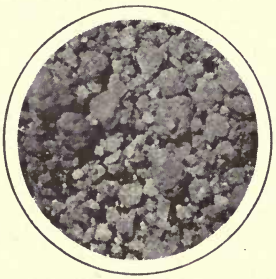

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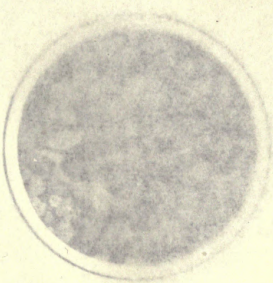

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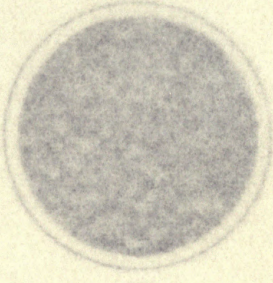

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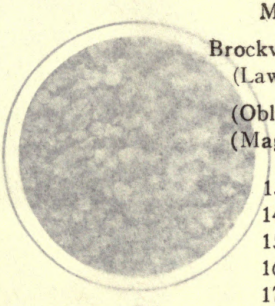
EXPLANATION OF PLATE VIII.

Microphotographe

Brockville Sand,
(Lawson's Foundry)

(Oblique reflected light)
(Magnification—12 diams.)

13. After 1st. Burn,
14. „ 3rd. „
15. „ 4th. „
16. „ 5th. „
17. „ 7th. „
18. No. 0 Albany Fresh Sand.



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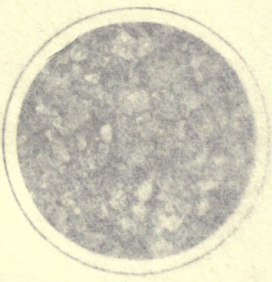

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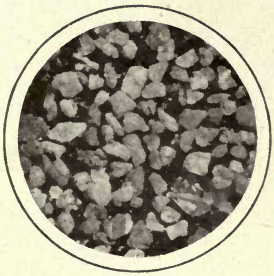
Explanation of Plate VIII.

Microphotographs

Rockville Sand,
(Lawson's Foundry)

(Oblique reflected light)
(Magnification—12 diams.)

13. After 1st. Burn,
14. " 3rd. "
15. " 4th. "
16. " 5th. "
17. " 7th. "
18. No. 0 Albany Fresh Sand.



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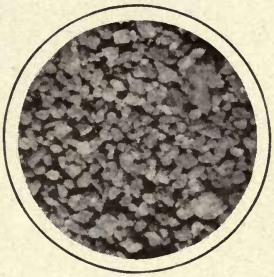

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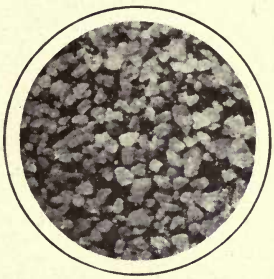

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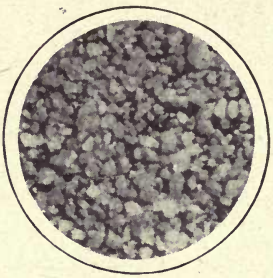

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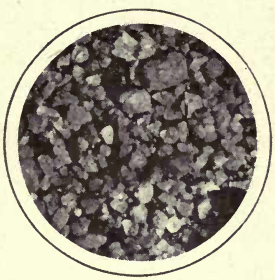

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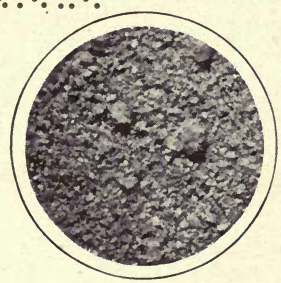

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